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Development of Ultra-high Mechanical Damping Structures Based on Nano-scale Properties of Shape Memory Alloys

Jose San Juan

Universidad del Pais Vasco
Department of Physics of Condensed Matter
Facultd de Ciencia y Tecnologia
Bilbao, Spain 48080

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Universidad del Pais Vasco
Department of Physics of Condensed Matter
Facultd de Ciencia y Tecnologia
Bilbao, Spain 48080

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14. ABSTRACT

This report results from a contract tasking Universidad del Pais Vasco as follows: The objective of the project is explore micro- and nano-scale pillars fabricated from Cu-Al-Ni shape memory alloys (SMA) to evaluate their potential for ultra-high mechanical damping. This study is spurned by recent discovery by the grantee that micro/nano pillars milled from Cu-Al-Ni SMA exhibit anomalously high mechanical damping compared to other materials. The project consists of two phases, the second being an option based on progress in the first. Phase one tasks include: (1) growing oriented single crystals of Cu-Al-Ni SMA and cutting thin slides and polishing, (2) producing micro-pillar arrays on the single crystal slides by optical microlithography, (3) characterizing the microstructure and martensitic transformation of the arrays, (4) testing mechanical and damping properties of individual pillars through nano-scale test techniques and compare to previous results for pillars produced using focused ion beam, and (5) design micro-compression test for the multi-pillar array and evaluate damping performance of the arrays. If results warrant, phase two will focus on production of nano-pillars by optical interferential nanolithography and e-beam lithography (and compare results of the two techniques), then characterize microstructure, martensitic transformation, and mechanical properties of the nano-pillar arrays. Finally, phase two will evaluate structure and performance of stacked multi-layer arrays.

15. SUBJECT TERMS

EOARD, shape memory alloys, mechanical damping

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Development of Ultra-High Mechanical Damping structures based on the Nano-Scale properties of Shape Memory Alloys.

Intermediate Report (22-July-2011)

According our previous contacts, in this report I let you know the present state of the project, which as I commented is technically delayed of six months, basically due to the task 1.2, as I will explain later. However we have developed complementary activities in order to reach a fast progress of the project in the next few months. So in the following I describe the state of each task of the project.

Task 1.1

The task 1.1 is fully accomplished and now we are able of producing Cu-Al-Ni shape memory alloys with the required concentration, and growing single crystals with different shapes and sizes.

We also can perform the thermal treatment of such single crystals to give them the superelastic and shape memory properties.

Task 1.2

This task is basically the reason of the delay in the development of the project.

Indeed, in the original proposal of the project, this task was scheduled to be developed at the clean rooms of the MTL laboratory of the MIT, where we previously produced several devices through an Outreach Program. However, since November 2010 my contact at the MTL (the Director of Operations) do not answered my e-mails and finally the Outreach Program cannot be renewed. Consequently I looked for another local laboratory in Spain in which I could be able of producing the micro pillar arrays by optical lithography. Negotiations are in progress but not yet successful.

To solve the problem I decided to use the most advanced techniques of optical interferential nano-lithography and e-beam lithography, originally scheduled for the second 12 month period, as Task 2.1. I have already the agreements to start with these production methods by the beginning of September, and it is expected that the first pillar arrays will be produced along October.

In the mean time, we have in parallel start the production of small arrays of micro-pillars directly by the Focused Ion Beam (FIB) technique. They will be ready in September.

Task 1.3

Obviously the limitations in the production of micro-pillar arrays delay any characterization of it.

However, we have already received and installed by the end of May (it was scheduled for beginning March) the new non-contact Scanning Probe Microscope, the XE-100 from Park Systems, which will be used to quantitatively characterize the topography of the pillar arrays. We show in Figure 1 the picture of such equipment.

Task1.4

The testing of the pillars and arrays by nano-indentation was also delayed.

However, we have already received and installed by the end of May (it was scheduled for beginning March) the new nano-indenter, the Tribo-Indenter 950 from Hysitron. This equipment will be used for all the nano-compression tests to study the mechanical and damping behavior of the individual pillars and arrays. We show in Figure 2 the picture of such equipment.

Task 1.5

We have already designed the testing procedures and methodology to measure the damping behavior of the pillar arrays, but as it has not been applied, it should be probably optimized just after the first tests became available.

I may conclude that in spite of the cumulate delay, I hope than in the next few month we will be able of doing large advances in the development of the project.

José San Juan

Professor of Physical Metallurgy

Figure 1: Scanning Probe Microscope XE-100 from Park Systems. General view of the installation and detail of the microscope inside of the acoustic isolation chamber.

Figure 2: Nano-Indenter TI-950 from Hysitron. General view of the installation and detail of the measuring heads, with (from left to right) the low load transducer, the high load transducer and the optical microscope.